Lab 3.7 - Student Notebook

Overview

This lab is a continuation of the guided labs in Module 3.

In this lab, you will create a hyperparameter tuning job to tune the model that you created previously. You will then compare the metrics of the two models.

Introduction to the business scenario

You work for a healthcare provider, and want to improve the detection of abnormalities in orthopedic patients.

You are tasked with solving this problem by using machine learning (ML). You have access to a dataset that contains six biomechanical features and a target of *normal* or *abnormal*. You can use this dataset to train an ML model to predict if a patient will have an abnormality.

About this dataset

This biomedical dataset was built by Dr. Henrique da Mota during a medical residence period in the Group of Applied Research in Orthopaedics (GARO) of the Centre Médico-Chirurgical de Réadaptation des Massues, Lyon, France. The data has been organized in two different, but related, classification tasks.

The first task consists in classifying patients as belonging to one of three categories:

- *Normal* (100 patients)
- *Disk Hernia* (60 patients)
- *Spondylolisthesis* (150 patients)

For the second task, the categories *Disk Hernia* and *Spondylolisthesis* were merged into a single category that is labeled as *abnormal*. Thus, the second task consists in classifying patients as belonging to one of two categories: *Normal* (100 patients) or *Abnormal* (210 patients).

Attribute information

Each patient is represented in the dataset by six biomechanical attributes that are derived from the shape and orientation of the pelvis and lumbar spine (in this order):

- Pelvic incidence
- Pelvic tilt
- Lumbar lordosis angle
- Sacral slope
- Pelvic radius
- Grade of spondylolisthesis

The following convention is used for the class labels:

- DH (Disk Hernia)
- Spondylolisthesis (SL)
- Normal (NO)
- Abnormal (AB)

For more information about this dataset, see the Vertebral Column dataset webpage.

Dataset attributions

This dataset was obtained from: Dua, D. and Graff, C. (2019). UCI Machine Learning Repository (http://archive.ics.uci.edu/ml). Irvine, CA: University of California, School of Information and Computer Science.

Lab setup

Because this solution is split across several labs in the module, you run the following cells so that you can load the data and train the model to be deployed.

Note: The setup can take up to 5 minutes to complete.

Importing the data, and training, testing and validating the model

By running the following cells, the data will be imported, and the model will be trained, tested and validated and ready for use.

Note: The following cells represent the key steps in the previous labs.

In order to tune the model it must be ready, then you can tweak the mdoel with hyperparameters later in step 2.

```
bucket='c169682a4380825l11238694t1w331889752698-labbucket-
mg11uezvnrkw'

import time
start = time.time()
import warnings, requests, zipfile, io
warnings.simplefilter('ignore')
import pandas as pd
from scipy.io import arff

import os
import boto3
import sagemaker
from sagemaker.image_uris import retrieve
from sklearn.model_selection import train_test_split
```

```
from sklearn.metrics import roc_auc_score, roc_curve, auc, confusion_matrix
import seaborn as sns
import matplotlib.pyplot as plt
```

```
sagemaker.config INFO - Not applying SDK defaults from location: /etc/xdg/sagemaker/config.yaml
sagemaker.config INFO - Not applying SDK defaults from location: /home/ec2-user/.config/sagemaker/config.yaml
```

Note: The following cell takes approximately **10** minutes to complete. Observe the code and how it processes, this will help you to better understand what is going on in the background. Keep in mind that this cell completes all the steps you did in previous labs in this module including:

- Importing the data
- Loading the data into a dataframe
- Splitting the data into training, test and validation datasets
- Uploading the split datasets to S3
- Training, testing and validating the model with the datasets

```
%%time

def plot_roc(test_labels, target_predicted_binary):
    TN, FP, FN, TP = confusion_matrix(test_labels, target_predicted_binary).ravel()
    # Sensitivity, hit rate, recall, or true positive rate
    Sensitivity  = float(TP)/(TP+FN)*100
    # Specificity or true negative rate
    Specificity  = float(TN)/(TN+FP)*100
    # Precision or positive predictive value
    Precision = float(TP)/(TP+FP)*100
    # Negative predictive value
    NPV = float(TN)/(TN+FN)*100
    # Fall out or false positive rate
    FPR = float(FP)/(FP+TN)*100
    # False negative rate
    FNR = float(FN)/(TP+FN)*100
    # False discovery rate
    FDR = float(FP)/(TP+FP)*100
    # Overall accuracy
    ACC = float(TP+TN)/(TP+FP+FN+TN)*100

    print(f"Sensitivity or TPR: {Sensitivity}%")
    print(f"Specificity or TNR: {Specificity}%")
    print(f"Precision: {Precision}%")
    print(f"Negative Predictive Value: {NPV}%")
    print( f"False Positive Rate: {FPR}%")
    print(f"False Negative Rate: {FNR}%")
```

```
    print(f"False Discovery Rate: {FDR}%" )
    print(f"Accuracy: {ACC}%")

    test_labels = test.iloc[:,0];
    print("Validation AUC", roc_auc_score(test_labels,
target_predicted_binary) )

    fpr, tpr, thresholds = roc_curve(test_labels,
target_predicted_binary)
    roc_auc = auc(fpr, tpr)

    plt.figure()
    plt.plot(fpr, tpr, label='ROC curve (area = %0.2f)' % (roc_auc))
    plt.plot([0, 1], [0, 1], 'k--')
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('Receiver operating characteristic')
    plt.legend(loc="lower right")

    # create the axis of thresholds (scores)
    ax2 = plt.gca().twinx()
    ax2.plot(fpr, thresholds, markeredgecolor='r',linestyle='dashed',
color='r')
    ax2.set_ylabel('Threshold',color='r')
    ax2.set_ylim([thresholds[-1],thresholds[0]])
    ax2.set_xlim([fpr[0],fpr[-1]])

    print(plt.figure())

def plot_confusion_matrix(test_labels, target_predicted):
    matrix = confusion_matrix(test_labels, target_predicted)
    df_confusion = pd.DataFrame(matrix)
    colormap = sns.color_palette("BrBG", 10)
    sns.heatmap(df_confusion, annot=True, fmt='.2f', cbar=None,
cmap=colormap)
    plt.title("Confusion Matrix")
    plt.tight_layout()
    plt.ylabel("True Class")
    plt.xlabel("Predicted Class")
    plt.show()


f_zip =
'http://archive.ics.uci.edu/ml/machine-learning-databases/00212/verteb
ral_column_data.zip'
r = requests.get(f_zip, stream=True)
Vertebral_zip = zipfile.ZipFile(io.BytesIO(r.content))
Vertebral_zip.extractall()
```

```
data = arff.loadarff('column_2C_weka.arff')
df = pd.DataFrame(data[0])

class_mapper = {b'Abnormal':1,b'Normal':0}
df['class']=df['class'].replace(class_mapper)

cols = df.columns.tolist()
cols = cols[-1:] + cols[:-1]
df = df[cols]

train, test_and_validate = train_test_split(df, test_size=0.2,
random_state=42, stratify=df['class'])
test, validate = train_test_split(test_and_validate, test_size=0.5,
random_state=42, stratify=test_and_validate['class'])

prefix='lab3'

train_file='vertebral_train.csv'
test_file='vertebral_test.csv'
validate_file='vertebral_validate.csv'

s3_resource = boto3.Session().resource('s3')
def upload_s3_csv(filename, folder, dataframe):
    csv_buffer = io.StringIO()
    dataframe.to_csv(csv_buffer, header=False, index=False )
    s3_resource.Bucket(bucket).Object(os.path.join(prefix, folder,
filename)).put(Body=csv_buffer.getvalue())

upload_s3_csv(train_file, 'train', train)
upload_s3_csv(test_file, 'test', test)
upload_s3_csv(validate_file, 'validate', validate)

container = retrieve('xgboost',boto3.Session().region_name,'1.0-1')

hyperparams={"num_round":"42",
             "eval_metric": "auc",
             "objective": "binary:logistic",
             "silent" : 1}

s3_output_location="s3://{}/{}/output/".format(bucket,prefix)
xgb_model=sagemaker.estimator.Estimator(container,
                                       sagemaker.get_execution_role(),
                                       instance_count=1,
                                       instance_type='ml.m5.2xlarge',
                                       output_path=s3_output_location,
                                        hyperparameters=hyperparams,

sagemaker_session=sagemaker.Session())
```

```
train_channel = sagemaker.inputs.TrainingInput(
    "s3://{}/{}/train/".format(bucket,prefix,train_file),
    content_type='text/csv')

validate_channel = sagemaker.inputs.TrainingInput(
    "s3://{}/{}/validate/".format(bucket,prefix,validate_file),
    content_type='text/csv')

data_channels = {'train': train_channel, 'validation':
validate_channel}

xgb_model.fit(inputs=data_channels, logs=False)

batch_X = test.iloc[:,1:];

batch_X_file='batch-in.csv'
upload_s3_csv(batch_X_file, 'batch-in', batch_X)

batch_output = "s3://{}/{}/batch-out/".format(bucket,prefix)
batch_input = "s3://{}/{}/batch-
in/{}".format(bucket,prefix,batch_X_file)

xgb_transformer = xgb_model.transformer(instance_count=1,
                                       instance_type='ml.m5.2xlarge',
                                       strategy='MultiRecord',
                                       assemble_with='Line',
                                       output_path=batch_output)

xgb_transformer.transform(data=batch_input,
                         data_type='S3Prefix',
                         content_type='text/csv',
                         split_type='Line')
xgb_transformer.wait(logs=False)
```

```
INFO:sagemaker:Creating training-job with name: sagemaker-xgboost-
2025-08-17-16-50-44-880


2025-08-17 16:50:46 Starting - Starting the training job.
2025-08-17 16:50:59 Starting - Preparing the instances for training...
2025-08-17 16:51:20 Downloading - Downloading input data..
2025-08-17 16:51:35 Downloading - Downloading the training image......
2025-08-17 16:52:10 Training - Training image download completed.
Training in progress.....
2025-08-17 16:52:36 Uploading - Uploading generated training model..
2025-08-17 16:52:49 Completed - Training job completed

INFO:sagemaker:Creating model with name: sagemaker-xgboost-2025-08-17-
16-52-51-828
INFO:sagemaker:Creating transform job with name: sagemaker-xgboost-
2025-08-17-16-52-52-370
```

```
...........................
..!
CPU times: user 1.52 s, sys: 135 ms, total: 1.65 s
Wall time: 7min 6s
```

Step 1: Getting model statistics

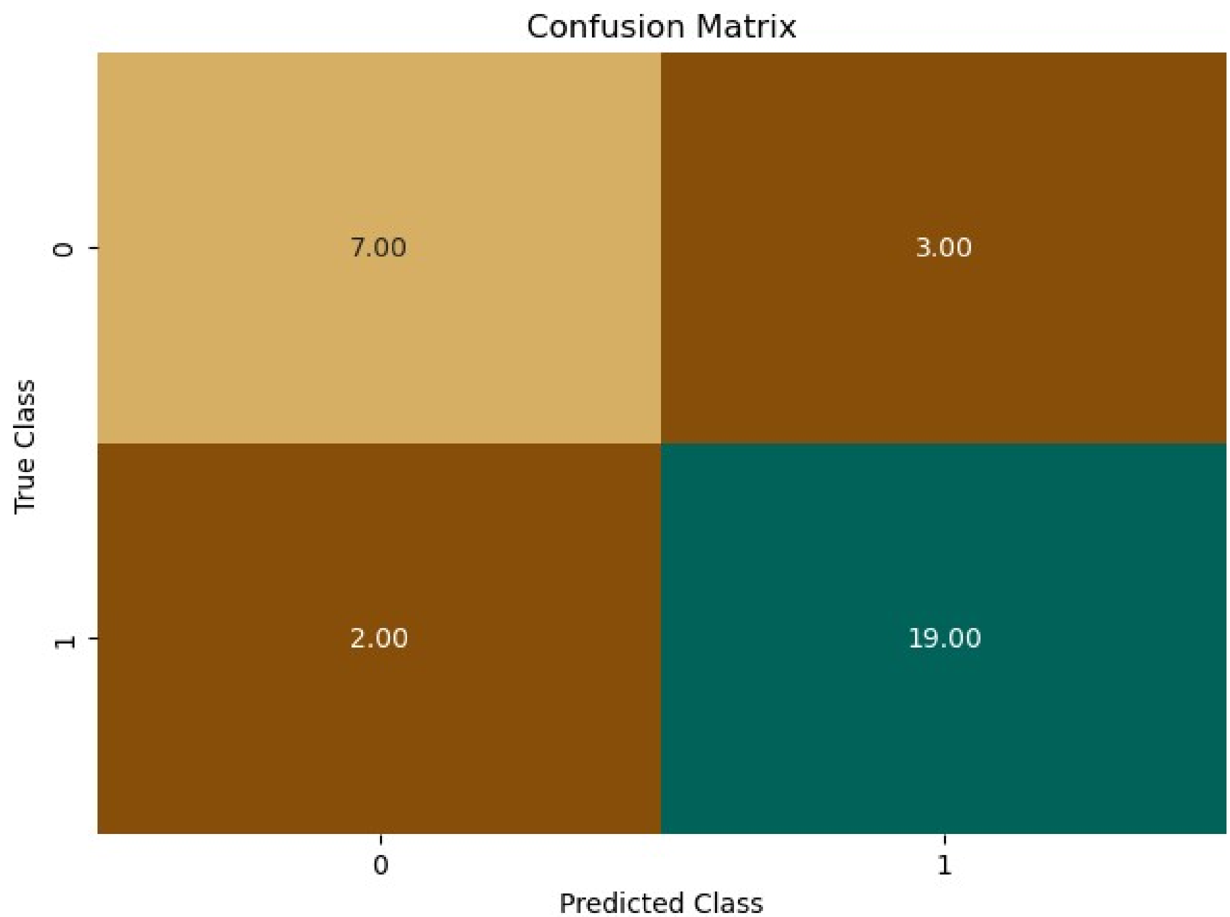
Before you tune the model, re-familiarize yourself with the current model's metrics.

The setup performed a batch prediction, so you must read in the results from Amazon Simple Storage Service (Amazon S3).

```
s3 = boto3.client('s3')
obj = s3.get_object(Bucket=bucket, Key="{}/batch-
out/{}".format(prefix,'batch-in.csv.out'))
target_predicted =
pd.read_csv(io.BytesIO(obj['Body'].read()),names=['class'])

def binary_convert(x):
    threshold = 0.5
    if x > threshold:
        return 1
    else:
        return 0

target_predicted_binary =
target_predicted['class'].apply(binary_convert)
test_labels = test.iloc[:,0]
```

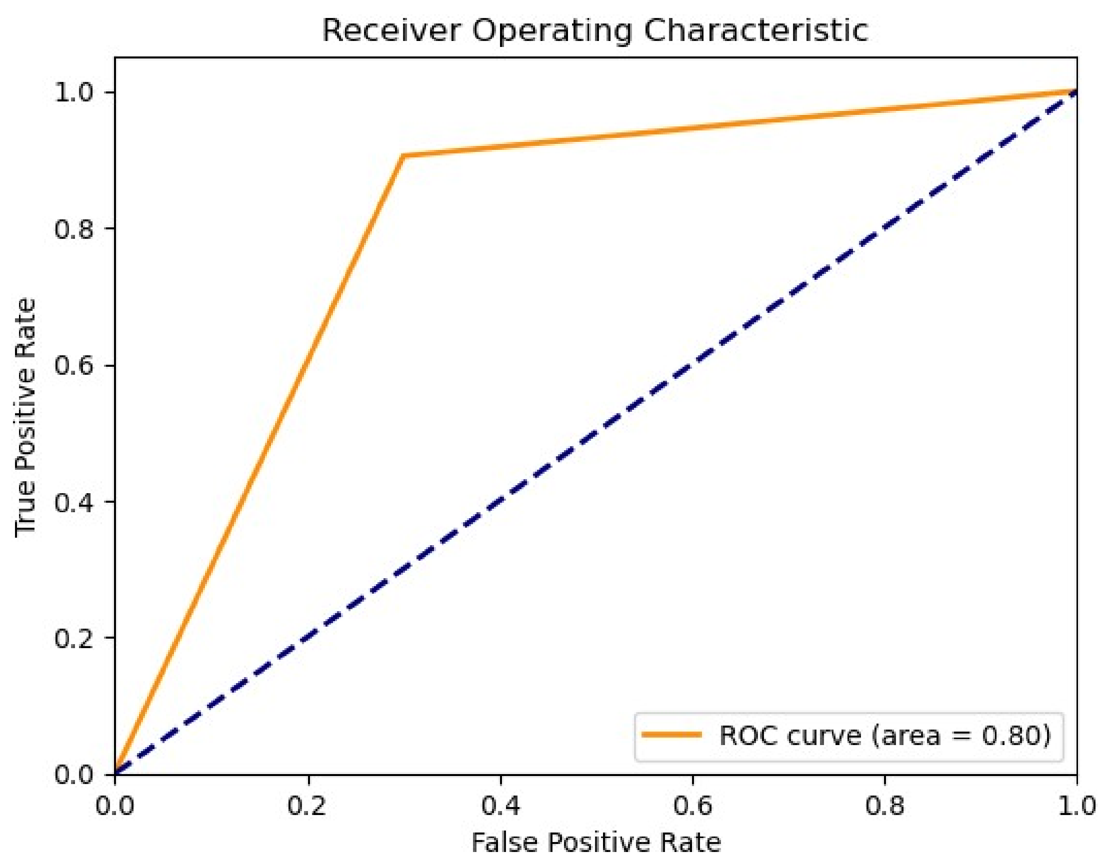
Plot the confusion matrix and the receiver operating characteristic (ROC) curve for the original model.

```
plot_confusion_matrix(test_labels, target_predicted_binary)
```




```
import numpy as np

print("Test labels NaN/Inf:", np.any(np.isnan(test_labels)),
np.any(np.isinf(test_labels)))
print("Predictions NaN/Inf:",
np.any(np.isnan(target_predicted_binary)),
np.any(np.isinf(target_predicted_binary)))

Test labels NaN/Inf: False False
Predictions NaN/Inf: False False

test_labels = np.nan_to_num(test_labels, nan=0, posinf=1, neginf=0)
target_predicted_binary = np.nan_to_num(target_predicted_binary,
nan=0, posinf=1, neginf=0)

print("Min prediction:", np.min(target_predicted_binary))
print("Max prediction:", np.max(target_predicted_binary))

Min prediction: 0
Max prediction: 1
```

```
from sklearn.metrics import roc_curve, auc
import matplotlib.pyplot as plt

def plot_roc(y_true, y_score):
    fpr, tpr, _ = roc_curve(y_true, y_score)
    roc_auc = auc(fpr, tpr)

    plt.figure()
    plt.plot(fpr, tpr, color='darkorange', lw=2, label=f'ROC curve
(area = {roc_auc:.2f})')
    plt.plot([0, 1], [0, 1], color='navy', lw=2, linestyle='--')
    plt.xlim([0.0, 1.0])
    plt.ylim([0.0, 1.05])  # Slightly above 1.0 to see the top
    plt.xlabel('False Positive Rate')
    plt.ylabel('True Positive Rate')
    plt.title('Receiver Operating Characteristic')
    plt.legend(loc="lower right")
    plt.show()

plot_roc(test_labels, target_predicted_binary)
```



This plot gives you a starting point. Make a note of the *Validation area under the curve (AUC)*. You will use it later to check your tuned model to see if it's better.

Step 2: Creating a hyperparameter tuning job

A hyperparameter tuning job can take several hours to complete, depending on the value ranges that you provide. To simplify this task, the parameters used in this step are a subset of the recommended ranges. They were tuned to give good results in this lab, without taking multiple hours to complete.

For more information about the parameters to tune for XGBoost, see Tune an XGBoost Model in the AWS Documentation.

Because this next cell can take approximately **45** minutes to complete, go ahead and run the cell. You will examine what's happening, and why these hyperparameter ranges were chosen.

```
%%time
from sagemaker.tuner import IntegerParameter, CategoricalParameter,
ContinuousParameter, HyperparameterTuner

xgb = sagemaker.estimator.Estimator(container,

role=sagemaker.get_execution_role(),
                                    instance_count= 1, # make sure you
have limit set for these instances
                                    instance_type='ml.m4.xlarge',

output_path='s3://{}/{}/output'.format(bucket, prefix),

sagemaker_session=sagemaker.Session())


xgb.set_hyperparameters(eval_metric='error@.40',
                        objective='binary:logistic',
                        num_round=42)

hyperparameter_ranges = {'alpha': ContinuousParameter(0, 100),
                         'min_child_weight': ContinuousParameter(1,
5),
                         'subsample': ContinuousParameter(0.5, 1),
                         'eta': ContinuousParameter(0.1, 0.3),
                         'num_round': IntegerParameter(1,50)
                         }

objective_metric_name = 'validation:error'
objective_type = 'Minimize'

tuner = HyperparameterTuner(xgb,
                            objective_metric_name,
                            hyperparameter_ranges,
                            max_jobs=10, # Set this to 10 or above
depending upon budget & available time.
                            max_parallel_jobs=1,
```

```
                                objective_type=objective_type,
                                early_stopping_type='Auto')

tuner.fit(inputs=data_channels, include_cls_metadata=False)
tuner.wait()
```

```
WARNING:sagemaker.estimator:No finished training job found associated
with this estimator. Please make sure this estimator is only used for
building workflow config
WARNING:sagemaker.estimator:No finished training job found associated
with this estimator. Please make sure this estimator is only used for
building workflow config
INFO:sagemaker:Creating hyperparameter tuning job with name:
sagemaker-xgboost-250817-1703

......................................................................
....................................................!
!
CPU times: user 765 ms, sys: 21.9 ms, total: 787 ms
Wall time: 10min 31s
```

First, you will create the model that you want to tune.

```
xgb = sagemaker.estimator.Estimator(container,

role=sagemaker.get_execution_role(),
                                   instance_count= 1, # make sure you
have limit set for these instances
                                   instance_type='ml.m4.xlarge',

output_path='s3://{}/{}/output'.format(bucket, prefix),

sagemaker_session=sagemaker.Session())

xgb.set_hyperparameters(eval_metric='[error@.40]',
                        objective='binary:logistic',
                        num_round=42)
```

Notice that the *eval_metric* of the model was changed to *error@.40*, with a goal of minimizing that value.

error is the binary classification error rate. It's calculated as *#(wrong cases)/#(all cases)*. For predictions, the evaluation will consider the instances that have a prediction value larger than 0.4 to be positive instances, and the others as negative instances.

Next, you must specify the hyperparameters that you want to tune, in addition to the ranges that you must select for each parameter.

The hyperparameters that have the largest effect on XGBoost objective metrics are:

- alpha

- min_child_weight
- subsample
- eta
- num_round

The recommended tuning ranges can be found in the AWS Documentation at Tune an XGBoost Model.

For this lab, you will use a *subset* of values. These values were obtained by running the tuning job with the full range, then minimizing the range so that you can use fewer iterations to get better performance. Though this practice isn't strictly realistic, it prevents you from waiting several hours in this lab for the tuning job to complete.

```
hyperparameter_ranges = {'alpha': ContinuousParameter(0, 100),
                         'min_child_weight': ContinuousParameter(1, 5),
                         'subsample': ContinuousParameter(0.5, 1),
                         'eta': ContinuousParameter(0.1, 0.3),
                         'num_round': IntegerParameter(1,50)
                         }
```

You must specify how you are rating the model. You could use several different objective metrics, a subset of which applies to a binary classifcation problem. Because the evaluation metric is **error**, you set the objective to *error*.

```
objective_metric_name = 'validation:error'
objective_type = 'Minimize'
```

Finally, you run the tuning job.

```
tuner = HyperparameterTuner(xgb,
                            objective_metric_name,
                            hyperparameter_ranges,
                            max_jobs=10, # Set this to 10 or above depending upon budget & available time.
                            max_parallel_jobs=1,
                            objective_type=objective_type,
                            early_stopping_type='Auto')

tuner.fit(inputs=data_channels, include_cls_metadata=False)
tuner.wait()
```

Wait until the training job is finished. It might take up to **45** minutes. While you are waiting, observe the job status in the console, as described in the following instructions.

To monitor hyperparameter optimization jobs:

1. In the AWS Management Console, on the **Services** menu, choose **Amazon SageMaker**.

2. Choose **Training > Hyperparameter tuning jobs**.

3. You can check the status of each hyperparameter tuning job, its objective metric value, and its logs.

After the training job is finished, check the job and make sure that it completed successfully.

```
boto3.client('sagemaker').describe_hyper_parameter_tuning_job(
    HyperParameterTuningJobName=tuner.latest_tuning_job.job_name)
['HyperParameterTuningJobStatus']
```

```
'Completed'
```

Step 3: Investigating the tuning job results

Now that the job is complete, there should be 10 completed jobs. One of the jobs should be marked as the best.

You can examine the metrics by getting *HyperparameterTuningJobAnalytics* and loading that data into a pandas DataFrame.

```
from pprint import pprint
from sagemaker.analytics import HyperparameterTuningJobAnalytics

tuner_analytics =
HyperparameterTuningJobAnalytics(tuner.latest_tuning_job.name,
sagemaker_session=sagemaker.Session())

df_tuning_job_analytics = tuner_analytics.dataframe()

# Sort the tuning job analytics by the final metrics value
df_tuning_job_analytics.sort_values(
    by=['FinalObjectiveValue'],
    inplace=True,
    ascending=False if tuner.objective_type == "Maximize" else True)

# Show detailed analytics for the top 20 models
df_tuning_job_analytics.head(20)
```

```
       alpha       eta  min_child_weight  num_round  subsample  \
1   8.146750  0.160798          4.812085       11.0   0.923510
2   3.504323  0.115582          2.443217       46.0   0.649053
3   6.062161  0.171126          4.510051        1.0   0.862938
4   0.206641  0.260575          4.633063       35.0   0.644514
7  14.464436  0.180165          4.618192       29.0   0.841506
0  94.073729  0.289897          1.413511       33.0   0.819255
5  60.276010  0.125866          3.001416       36.0   0.887458
6  50.588508  0.215777          3.144597       17.0   0.655507
```

```
8  69.609011  0.252054          2.760874       11.0   0.589940
9  69.336306  0.278731          4.831002       46.0   0.797561

                              TrainingJobName TrainingJobStatus  \
1  sagemaker-xgboost-250817-1703-009-49b1e041         Completed
2  sagemaker-xgboost-250817-1703-008-99d55f2f         Completed
3  sagemaker-xgboost-250817-1703-007-e344fe7c         Completed
4  sagemaker-xgboost-250817-1703-006-7cdc97a7         Completed
7  sagemaker-xgboost-250817-1703-003-4d538c69         Completed
0  sagemaker-xgboost-250817-1703-010-43e9a55e         Completed
5  sagemaker-xgboost-250817-1703-005-24e0e587         Completed
6  sagemaker-xgboost-250817-1703-004-f9128ed5         Completed
8  sagemaker-xgboost-250817-1703-002-dea4c59d           Stopped
9  sagemaker-xgboost-250817-1703-001-f756bba9         Completed

   FinalObjectiveValue         TrainingStartTime
TrainingEndTime  \
1              0.09677 2025-08-17 17:12:22+00:00 2025-08-17
17:12:56+00:00
2              0.09677 2025-08-17 17:11:29+00:00 2025-08-17
17:12:03+00:00
3              0.09677 2025-08-17 17:10:36+00:00 2025-08-17
17:11:10+00:00
4              0.09677 2025-08-17 17:09:42+00:00 2025-08-17
17:10:16+00:00
7              0.12903 2025-08-17 17:07:13+00:00 2025-08-17
17:07:47+00:00
0              0.67742 2025-08-17 17:13:15+00:00 2025-08-17
17:13:49+00:00
5              0.67742 2025-08-17 17:08:49+00:00 2025-08-17
17:09:23+00:00
6              0.67742 2025-08-17 17:08:01+00:00 2025-08-17
17:08:35+00:00
8              0.67742 2025-08-17 17:06:33+00:00 2025-08-17
17:07:05+00:00
9              0.67742 2025-08-17 17:04:11+00:00 2025-08-17
17:06:06+00:00

   TrainingElapsedTimeSeconds
1                        34.0
2                        34.0
3                        34.0
4                        34.0
7                        34.0
0                        34.0
5                        34.0
6                        34.0
8                        32.0
9                       115.0
```

You should be able to see the hyperparameters that were used for each job, along with the score. You could use those parameters and create a model, or you can get the best model from the hyperparameter tuning job.

```
attached_tuner =
HyperparameterTuner.attach(tuner.latest_tuning_job.name,
sagemaker_session=sagemaker.Session())
best_training_job = attached_tuner.best_training_job()
```

Now, you must attach to the best training job and create the model.

```
from sagemaker.estimator import Estimator
algo_estimator = Estimator.attach(best_training_job)

best_algo_model =
algo_estimator.create_model(env={'SAGEMAKER_DEFAULT_INVOCATIONS_ACCEPT
':"text/csv"})
```

```
2025-08-17 17:10:34 Starting - Found matching resource for reuse
2025-08-17 17:10:34 Downloading - Downloading the training image
2025-08-17 17:10:34 Training - Training image download completed.
Training in progress.
2025-08-17 17:10:34 Uploading - Uploading generated training model
2025-08-17 17:10:34 Completed - Resource reused by training job:
sagemaker-xgboost-250817-1703-007-e344fe7c
```

Then, you can use the transform method to perform a batch prediction by using your testing data. Remember that the testing data is data that the model has never seen before.

```
%%time
batch_output = "s3://{}/{}/batch-out/".format(bucket,prefix)
batch_input = "s3://{}/{}/batch-
in/{}".format(bucket,prefix,batch_X_file)

xgb_transformer = best_algo_model.transformer(instance_count=1,
                                       instance_type='ml.m4.xlarge',
                                       strategy='MultiRecord',
                                       assemble_with='Line',
                                       output_path=batch_output)


xgb_transformer.transform(data=batch_input,
                         data_type='S3Prefix',
                         content_type='text/csv',
                         split_type='Line')
xgb_transformer.wait(logs=False)
```

```
INFO:sagemaker:Creating model with name: sagemaker-xgboost-2025-08-17-
17-15-35-225
```

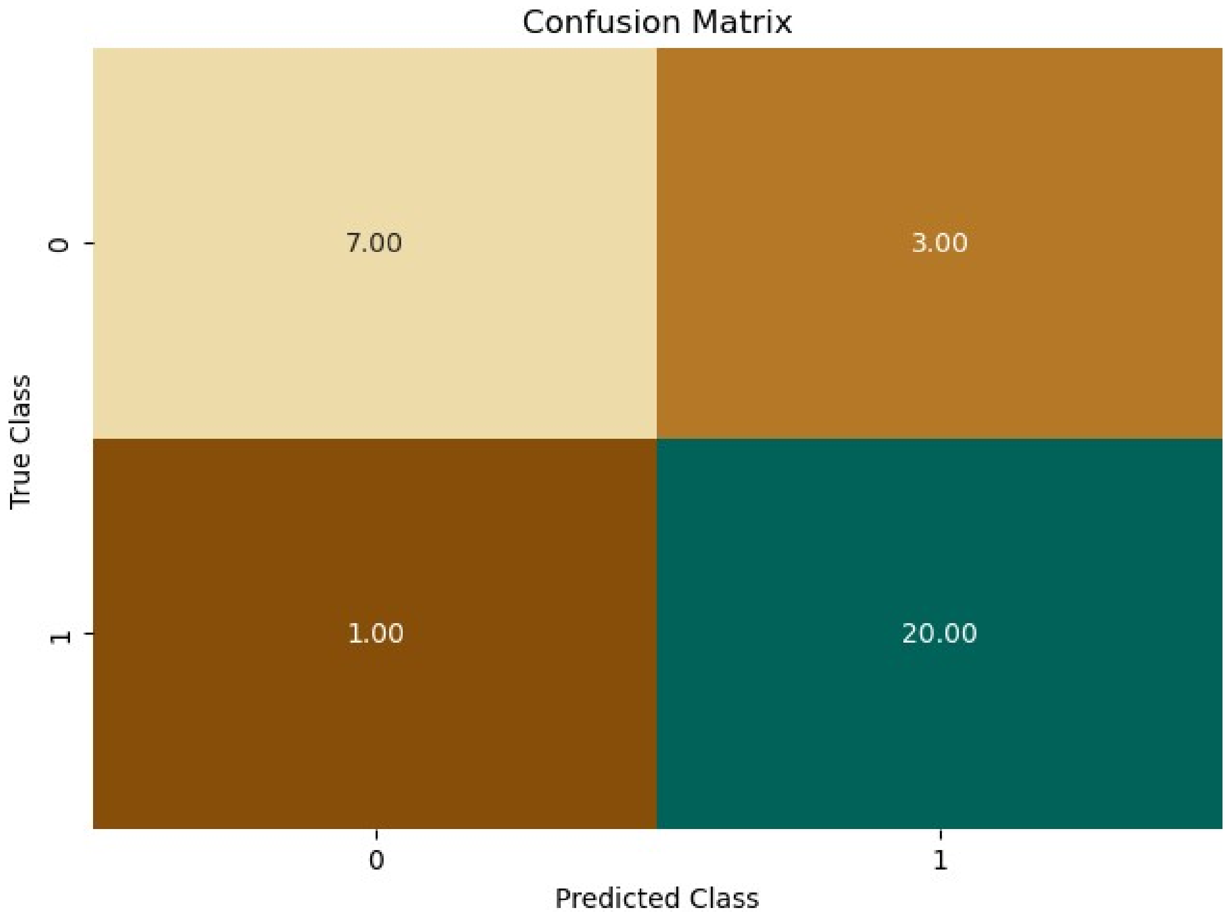
```
INFO:sagemaker:Creating transform job with name: sagemaker-xgboost-
2025-08-17-17-15-35-798

.......................................
..!
CPU times: user 771 ms, sys: 39.9 ms, total: 811 ms
Wall time: 6min 58s
```

Get the predicted target and the test labels of the model.

```
s3 = boto3.client('s3')
obj = s3.get_object(Bucket=bucket, Key="{}/batch-
out/{}".format(prefix,'batch-in.csv.out'))
best_target_predicted =
pd.read_csv(io.BytesIO(obj['Body'].read()),names=['class'])

def binary_convert(x):
    threshold = 0.5
    if x > threshold:
        return 1
    else:
        return 0

best_target_predicted_binary =
best_target_predicted['class'].apply(binary_convert)
test_labels = test.iloc[:,0]
```

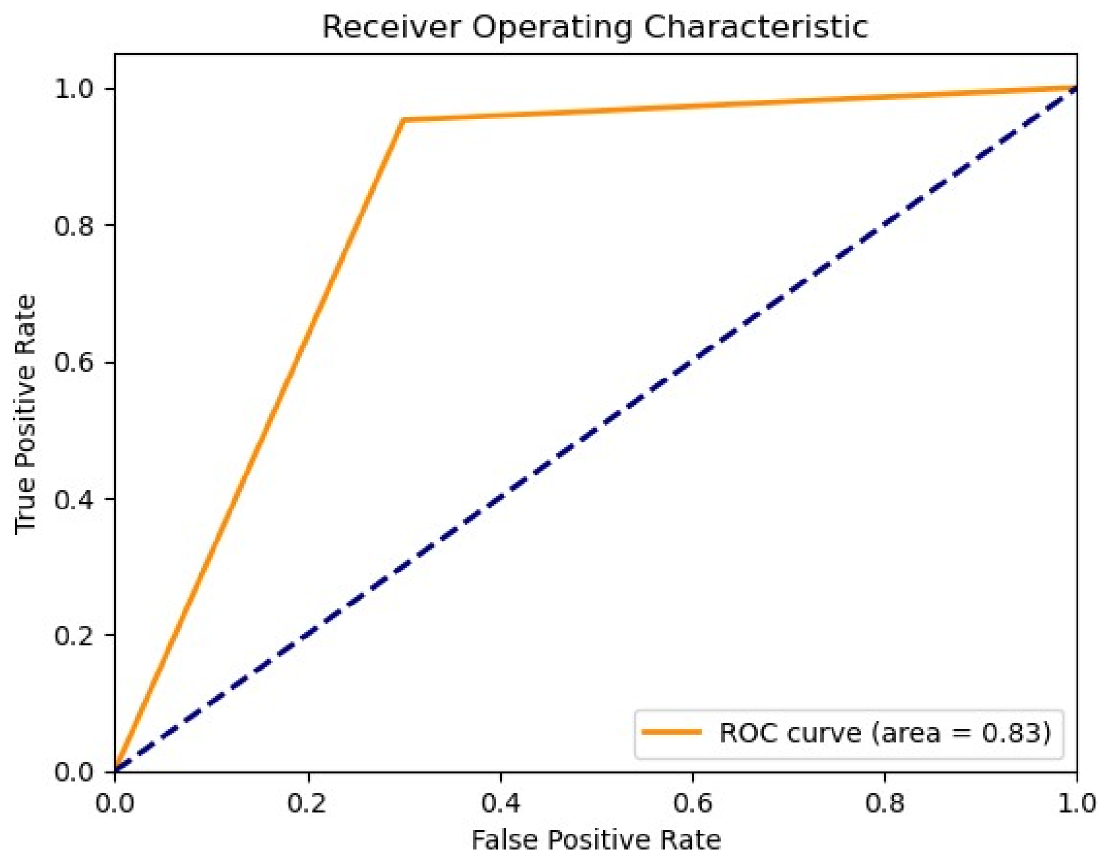
Plot a confusion matrix for your `best_target_predicted` and `test_labels`.

```
plot_confusion_matrix(test_labels, best_target_predicted_binary)
```



Plot the ROC chart.

```
plot_roc(test_labels, best_target_predicted_binary)
```



Question: How do these results differ from the original? Are these results better or worse?

You might not always see an improvement. There are a few reasons for this result:

- The model might already be good from the initial pass (what counts as *good* is subjective).
- You don't have a large amount of data to train with.
- You are using a *subset* of the hyperparameter tuning ranges to save time in this lab.

Increasing the hyperparameter ranges (as recommended by the documentation) and running more than 30 jobs will typically improve the model. However, this process will take 2-3 hours to complete.

Congratulations!

You have completed this lab, and you can now end the lab by following the lab guide instructions.